

Long-Term vs Short-Term Conservation Tillage

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1.0 INTRODUCTION

Every year, 2–12 million hectares or 0.3–0.8% of the world's arable land is rendered unsuitable for agricultural production through soil degradation. Wind and water erosion accounts for 84% of this degradation (den Biggelaar et al., 2004a). Lal (2007) reported that 1966 Mha of land worldwide is affected by soil degradation. Thus good management to protect the soil against degradation is necessary to meet the world's future needs for food and fibre (den Biggelaar et al., 2004b) and possibly renewable energy needs as well. Pimentel and Pimentel (2000) stated that 99% of food consumed by humans comes from the land. It is therefore imperative that we do everything possible to sustain and enhance our soil resource.

The challenge for Canadian agriculture is to ensure economic viability while both satisfying society's need for safe and nutritious food and conserving or enhancing the environment for future generations (Gilson 1989). Sustainable development was defined by Brundtland (1987) as: "economic growth that meets the needs of the present without compromising the ability of future generations to meet their own needs". At the 2002 Earth Summit on sustainable development held in Johannesburg, this definition was broadened and strengthened by linking global poverty, the environment and the use of natural resources to sustainable development (Anonymous 2002).

We have ample evidence to show that the most effective way of reducing soil degradation from wind and water erosion is by maintaining a residue cover and preferably with some standing stubble hence the interest in no-till production systems (Smika and Unger 1986). However, a no-till production system is only one of many important aspects of sustainability. Lal (2007) emphasizes that: "*Sustainable use of soil resources does not depend solely on the use of fertilizers, irrigation, improved varieties, and even no-till and mulch farming systems. It depends on the adoption of a holistic approach, in which all recommended components are combined in synergism. Judicious use of soil and water resources, based on soil-specific recommended technologies, is the guiding principle.*"

The objective of the paper is to discuss some of the major effects of no-till on soil properties and to also examine what we can expect after >25 years of no-till and continuous cropping on overall crop production and what it means for the Canadian prairies.

2.0 EFFECTS OF NO-TILL ON SOIL PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES

The long-term goal of prairie agriculture must be to sustain and enhance, if possible, our soil resource while at the same time provide economic benefits to the stewards of this resource and food for the rest of us. Wind and water erosion are the most important degrading factors, hence the need to adopt production practices that minimize these negative effects.

Two very important functions of soil are the transmission and the retention of water. These functions are critical for plant growth and the environment. Water is necessary for plant growth because of its effects on the movement of nutrients to the roots and in the plant and for cell growth. Water in the soil is also necessary to support fungal and bacterial communities and other organisms responsible for the cycling of nutrients. A healthy soil will encourage water infiltration to ensure ground water recharge and reduce the movement of sediments from surface water movement.

A large number of studies have been conducted in Western Canada and the northern Great Plains which shows how tillage and cropping systems impact fundamental soil properties and how some practices can increase soil degradation.

2.1 Soil Physical Processes. The first determinant of wind erosion potential is soil aggregation. Proper soil aggregation also has a large influence on microbial activity, soil tilth, aeration and water infiltration. Pikul et al. (2006) has even suggested that the level of soil aggregation could be used as an indicator of soil quality. Soil aggregates that are <0.84 mm are considered prone to wind erosion and if $>60\%$ of the aggregates are <0.84 , the soils would be classified as highly erodible (Anderson and Wendhardt 1966). The optimum soil structure would have an aggregate size $>1-3$ mm and these aggregate size distributions can be found under permanent grasses with large fibrous root systems, even after green manure crops or after frequent cropping (Campbell et al. 1993a). In the black soil zone, aggregate stability was closely related to long-term management such as frequent cropping, fertilization and use of legume and less to management practices the previous year (Campbell et al. 1993b). The same was observed in the brown and dark-brown soil zone and adopting chemical fallow rather than tillage fallow practices resulted in an increase in aggregate stability (Campbell et al. 1993a). Practices such as tillage and tillage fallow systems will reduce the size and overall proportion of large aggregates in the surface 2" of the soil.

When surface residues and standing stubble are maintained, as in no-till systems, some additional benefits are observed (Smika and Unger 1986). Surface crop residues will protect the soil surface against rain drop impact energy thereby protecting the soil structure, increasing infiltration, reducing runoff, reducing evaporation losses and trapping and holding more snow allowing for more available water for crop growth. More water for crop growth means more residues being returned to the soil thereby increasing overall soil health. In situations of limited residues, standing stubble is four times more effective than flat lain residues at stopping wind erosion hence the importance of having some standing stubble (Lyles and Allison 1981).

Franzluebbers and Arshad (1996) showed that no-till increased macroaggregation (>0.25 mm) and mean weight diameter of aggregates, even in coarse textured soils. They even suggested that the higher level of macroaggregation with no-till could lead to net increase in carbon sequestration in the form of soil organic matter, a concept that has since been verified. Arshad et al. (1999) also showed that with no-till, water retention could be increased with little change in soil bulk density due to a redistribution of pore size classes into more small pores and less large pores. They also noted better overall water infiltration into no-till soils. Better internal structure also leads to better carrying capacity of equipment and less potential for compaction.

2.2. Soil Chemical Processes: The soil chemical constituents of greatest interest for this paper is the impact of tillage and cropping systems on soil organic carbon and nitrogen and the discussion will be limited to these.

In the Brown soil zone, increases in soil organic carbon and nitrogen were closely related to the amount of crop residues returned to the soil and the nitrogen content of the residues. The amount of residues returned was dependent on the use of an appropriate fertility regime (Campbell and Zentner 1997; Campbell et al. 2007a). In three consecutive years of poor yields, one of which was a crop failure, a reduction in soil organic carbon and nitrogen was subsequently observed except for a rotation that included the winter cereal fall rye where increases were observed due to the ability to produce dry matter early in the growing season, at a time when evapo-transpiration is less. This evidence points to the merits of doing more work on winter cereals across the prairies. Their research also showed the importance of ensuring a positive nitrogen balance otherwise if nitrogen removal is greater than nitrogen input, a gradual decrease in soil organic C and N will occur. This further indicates the need to conserve and manage soil water appropriately in order to sustain crop growth which is necessary to sustain soil organic matter. The combination of no-till, tall stubble and proper fertility will greatly increase the potential to increase soil organic carbon and nitrogen as a result of higher grain yields due to increased water conservation, reductions in water losses from evaporation and increases in water use efficiency (Cutforth et al. 1997, 2002 and 2006).

In the Dark-brown soil zone, research from long-term studies at Lethbridge showed that if erosion can be controlled, the current practises involving continuous cropping with proper fertility and infrequent summer-fallowing, if required, and the use of chemical fallow rather than tillage fallow, soil organic carbon and nitrogen could be maintained (Janzen et al. 1997). They also indicated that adopting no-till combined with continuous cropping could possibly increase soil organic carbon.

It has been well documented in the Breton plots near Edmonton, a site in the Black soil zone, that the maintenance of soil organic matter is dependent on the continuous growth of crops or the addition of manures or the appropriate use of fertilizers to ensure optimum crop growth. The inclusion of forage crops can also provide added benefits (Juma et al. 1997). Other studies in the black soil zone at Indian Head and Melfort indicated that the increase in soil organic carbon was proportional to cropping frequency or the amount of residues returned to the soil, the use of a proper fertility regime or the inclusion of legume-grass forage crops (Campbell et al. 1997).

More recent studies have confirmed that when no-till is combined with continuous cropping, increases in soil organic carbon are observed (McConkey et al. 2003; Campbell et al. 2007b). As mentioned above, the increase in soil organic carbon and nitrogen will be directly related to crop production which in turn will determine the amount of crop residues returned to the soil. Management practices that encourage crop production and residue addition to the soil, taking into account the vagaries of the climate will enhance the soil resource.

2.3. Soil Biological Processes: Soil organic matter, as mentioned above, plays a key role in crop production and in describing overall soil health. When examining the microbial aspects of soils, the size of the microbial community is directly proportional to soil organic matter content and soil microbes are the principal mediators of nutrient cycling (Hamel et al. 2006). Although soil microbial biomass only represents a small proportion of overall soil organic matter, it is more dynamic than total soil organic matter. Because of this, it has been shown that soil microbial

biomass is a better indicator of how tillage systems and cropping systems impact soil health and the soil's productive capacity (Lupwayi et al. 1999; Campbell et al. 2001). Soil organic carbon and nitrogen, microbial biomass carbon (MBC), light fraction carbon (LFC), light fraction organic nitrogen (LFN) and wet aggregate stability were enhanced with increased cropping frequency, fertilization and also with the inclusion of green manure crops and legume hay crops but LFC, LFN, MBC and potentially mineralizable N were more sensitive to changes in cropping practices than simple measures of total soil organic carbon and nitrogen (Campbell et al. 2001).

When no-till is included as a factor, Lupwayi et al. (2004) noted that microbial biomass increased as well as the functional diversity and activity of microbes. They suggested that this would have a positive effect on decomposition processes by microbes of crop residues. In another study they observed that microbial biomass carbon turnover was higher with no-till than conventional tillage. Soon and Clayton (2003) also observed that N mineralization was also higher with no-till.

The three main factors describing the rate of residue decomposition is temperature, location of residues (on the soil surface vs buried) and the nitrogen content of residues (Janzen and Kucey 1988; Douglas and Rickman 1992). As temperature increases and the nitrogen content of residues increases, the rate of decomposition increases. Residues placed on the soil surface decompose at about two thirds the rate of buried residues. When the effects of no-till on soil microbial activity and diversity are superimposed, some interesting observations are noted. Residues lost nitrogen faster with tillage than no-till but overall crop yield and N uptake tended to be greater with no-till than with tillage (Soon et al. 2001). As well, nitrogen mineralization was always greater with no-till even though some initial immobilization of nitrogen was sometimes observed (Soon and Arshad 2004; Lupwayi et al. 2006a; Lupwayi et al. 2006b). It is argued that the slower rate of decomposition may allow for a longer period of nutrient release thereby supplying the crop with nutrients like nitrogen over a longer period of time during the growing season thereby minimizing potential nitrogen losses early in the growing season from adverse climatic conditions (Lupwayi et al. 2004).

3.0 EFFECTS OF CROP RESIDUES AND NO-TILL FOR EROSION CONTROL

The dry years of 2002 and 2003 in certain parts of the prairies demonstrated very well how crop residues and no-till can provide effective wind erosion control, even after crops like lentil, field pea or lentil. No serious widespread wind erosion events were recorded.

As with wind erosion, no-till is also effective against water erosion. Mostaghimi et al. (1992) evaluated the impact of reduced tillage and retained crop residues on soil erodibility (Table 1). Conventional tillage systems, even with 1500 kg-ha⁻¹ of residues, lost approximately 9 times the soil (513 kg ha⁻¹) as did the no-till system with no retained residues (72 kg ha⁻¹). The difference was even more startling given that the no-till plots were located on a 12% slope while the conventional till plots were located on a 9% slope.

Given that wind and water erosion are the leading causes of soil degradation and that no-till has the ability to reduce it to very low levels, it makes ample sense to research and develop these systems further and to encourage their widespread adoption.

Table 1: Effects of Residue Levels and Tillage Systems on Runoff and Sediment Losses (from Mostaghimi et al. 1992).

Tillage System	Residue Level kg ha⁻¹	Sediment Yield kg ha⁻¹
No-Till	0	72
	750	11
	1500	7
Conventional Tillage	0	2812
	750	1001
	1500	513

4.0 WHAT CAN WE EXPECT FROM NO-TILL 25 YEARS FROM NOW?

The previous sections established the positive effects of no-till when combined with continuous cropping and proper fertilization on soil health, soil organic matter accretion, development of more stable aggregates, more timely nutrient cycling, better nutrient uptake, protection against wind and water erosion and better overall crop production. With refinements in no-till production practices like the potential of tall standing stubble to enhance crop growth as a result of more water conserved, reduction in evaporation losses and increases in crop water use efficiencies, it is possible that the benefits in the drier areas can actually be enhanced further with no-till given the relationship between soil quality and the amount of residues returned to the soil.

There is interest in knowing what we can expect for the overall health of soils and their productive capacity as we look at the impact of no-till 20 and 25 years down the road. A series of experiments were established in 2002 to shed some light on this question.

Making changes in farming practises requires commitment, time and resources. Producers are interested in knowing the long-term benefits of these changes especially their economic impact. Most of the research work comparing no-till to conventional-till usually dealt with shorter time frames or longer time frames with only a small number of treatments. This makes it very difficult to assess the long-term agronomic and economic benefits of no-till.

4.1 Description of study:

In 2001, a unique opportunity presented itself. Jim Halford, a long-time no-till producer in the Indian Head area leased a field adjacent to his long-term 20 year+ no-till field. This adjacent field had been managed using a conventional crop-fallow cropping system. This opportunity provided us with the ability to quantify the magnitude of the long-term agronomic and economic benefits of direct seeding. The areas also allowed us to investigate a number of questions using various studies. A description of the cropping sequences of the two fields in question is given in Table 2.

The close proximity of the two contrasting fields allowed the opportunity to answer more questions regarding the long-term effects of direct seeding and continuous cropping on overall crop production. Results from two of the studies will be discussed. The first study was started in 2002 and is on-going with canola alternating with spring wheat using the same plots and fertilizer treatments so we can quantify the cumulative effects of these treatments. The study also evaluates the effects of P placement (side-band vs seed-placed) and different rates of N using a

no-till system. The second study looks at the response of wheat and field pea to different levels of phosphorus fertilizer. The study was started in 2003 and is on-going.

Table 2. Cropping histories of long-term and short term fields used in this study. No-till was initiated in 2001 on the short-term no-till field site.

Year	Long-Term No-Till Field	Year	Short-Term No-Till Field
1978-1983	No-Till Annual Cropping	1984-1998	Conventional Tillage Wheat/Fallow System
1984-90	Brome Grass Seed Production for 5 years and 2 years of hay		
1991	Chemical fallow	1999	Summerfallow
1992	Spring wheat	2000	Barley - Conventional Tillage
1993	Canola	2001	Canola
1994	Spring wheat	2002	Spring Wheat
1995	Canola	2003	Field Pea
1996	Spring wheat	2004	Spring wheat
1997	Canola	2005	Canola
1998	Spring wheat	2006	Spring wheat
1999	Lentil	2007	Canola
2000	Spring wheat		
2001	Canola		
2002	Spring wheat		
2003	Field pea		
2004	Spring wheat		
2005	Canola		
2006	Spring wheat		
2007	Canola		

4.2. Impact of short and long-term no-till on soil quality:

We also carried out a series of soil analyses from samples collected throughout the long-term and short-term no-till fields to determine soil quality characteristics at different landscapes positions and compare it to soil samples taken from adjacent areas of native prairie. A summary of the measurements is provided in Table 3. In the 0-15 cm soil layer, soil bulk density and total-N (NH_4+NO_3) were lowest for the native prairie soil and highest for the long-term no-till soils with similar values to short term no-till soils in the case of total N. Total N using the Hot-KCl extraction method was highest for the native prairie soil, intermediate for the long-term no-till soil and lowest for the short-term no-till soil. The values for the long-term no-till site were 75% of the value for the native soil while the short term no-till was less than half (47%). The differences in amino-N sugars between treatments were similar to the values for total N using the Hot-KCl extraction method except that the values for the short term was 60% of the native prairie soil. Similar results were obtained for the 15-30 cm soil layer except that the values in absolute terms were lower, a reflection of the fact that the most active soil layer in terms of nutrients and microbiological activity is usually found in the upper layers.

The KCl extraction method and the amino-N determinations both provide an estimate of the nitrogen releasing power of the soil. In both cases, the extent and direction of the values were very similar. These values corroborate the findings discussed in section 2.0 of this paper. Therefore going to a continuous cropping no-till system will enhance the productive capacity of soils over time and hopefully the overall health of the soil.

Table 3. The effects of length of no-till on selected soil quality attributes relative to native prairie for the 0-15 and 15-30 cm soil layer.

Variable	0-15 cm Depth				15-30 cm			
	Native	Long-term	Short-Term	p-value	Native	Long-term	Short-Term	p-value
Bulk Density (g cm^{-3})	0.99	1.40	1.47	0.001	1.34	1.34	1.38	Ns
$\text{NO}_3\text{-N kg ha}^{-1}$	3.1	8.6	5.3	0.001	1.1	4.1	2.7	0.002
$\text{NH}_4\text{-N kg ha}^{-1}$	2.4	3.3	1.1	ns	1.7	0.4	0	0.001
Total N kg ha^{-1}	5.5	11.9	6.5	0.03	2.8	4.5	2.7	0.02
Hot KCl $\text{NO}_3\text{-N kg ha}^{-1}$	12.6	20.4	13.9	0.009	4.8	7.7	5.5	0.03
Hot KCl $\text{NH}_4\text{-N kg ha}^{-1}$	65.3	38.0	22.5	0.001	29.3	15.1	11.9	0.003
Hot KCl Total N kg ha^{-1}	77.9	58.4	36.3	0.0001	34.1	22.8	17.5	0.018
Amino-N ppm	419	233	174	0.0001	217	130	104	0.006
Amino-N kg ha^{-1}	618	479	373	0.0001	424	256	212	0.0187
Organic C Mg ha^{-1}	51.4	46.1	37.0	0.0001	31.5	20.6	18.6	0.06

4.3. The effects of length of no-till on the response of wheat and canola to nitrogen fertilizers and phosphorus placement and on the response of wheat and field pea to phosphorus fertilizer.

4.3.1. Nitrogen Rate and Phosphorus Placement Study in Spring Wheat and Canola.

The plots were planted with a 12 row ConservaPaktm seeder with a row spacing of 30 cm (12" apart). The plots were always seeded in the first week of May. It is important to note that the crop sequence used was wheat-canola with each crop alternating every other year. In 2002, 2004 and 2006, the plots were seeded to spring wheat. In 2003, 2005 and 2007, the plots were seeded to canola. Only the years 2002-2006 are discussed. As well, the same treatments are applied to the same plots each year. This allows the opportunity to measure the cumulative effects of different rates of nitrogen over time on grain yield, grain protein and residual soil nitrate-nitrogen. The rates of nitrogen ranged from 0-120 kg ha⁻¹. We also included a treatment which compared one rate of phosphorus either seed-placed or side-banded at all rates of nitrogen.

With spring wheat, nitrogen concentration in the flag leaf, grain yield and grain protein content increased as rate of nitrogen increased for both the long-term and short-term no-till sites (Table 4). The response was very similar for both sites but the absolute values were higher for the long-term no-till site. The observed higher flag leaf nitrogen concentration from the long-term no-till site corroborates the observations that the long-term no-till site has a higher nitrogen releasing capacity as indicated in Table 3. It took 90 kg N/ha on the short-term site to achieve the same protein level as on the long-term site with 30 kg N/ha. This again is a reflection of the higher N releasing power of long-term no-till soils. Although only one rate of phosphorus was used, increasing rates of N increased the flag leaf concentration for phosphorus on both sites. The absolute differences were the higher on the long-term no-till site.

Similar observations to spring wheat were noted for canola although there was no clear pattern noted for grain protein as was the case for spring wheat (Table 5).

When residual nitrate-N levels were measured after 5 years, accumulations of agronomic importance were noted for only the high rate of N used (Table 6). As a rule, 60-90 kg N/ha is an optimum range for a yield response as observed for the yields of spring wheat and canola during the last 5 years. However, even the yearly use of 120 kg N/ha did not result in high accumulations of nitrate-nitrogen.

When comparing the effects of seed-placed phosphorus with the seed vs side-banded phosphorus with the nitrogen, no differences in grain yield were observed in both spring wheat and canola, regardless of the rate of nitrogen used (Table 7&8).

A nitrogen balance was done for the first five years comparing the amount of nitrogen added vs the amount of nitrogen removed (Table 9). With the long-term no-till site, an average of 60 kg N/ha was required to maintain a positive N balance while only 30 kg N/ha was required for the short-term site is a reflection of the lower grain yields recorded. It also reinforces the findings of Campbell and Zentner (1997) that a positive nitrogen balance is required in order to at least maintain soil organic matter. Given that the accumulation of nitrates was not observed with the intermediate rates of nitrogen on the short-term site may indicate that some nitrogen immobilization is taking place.

Table 4. The effects of length of no-till and nitrogen rate on leaf nitrogen and leaf phosphorus content, grain yield and grain protein in spring wheat.

N Rate (kg/ha)	Leaf Nitrogen (%)		Leaf Phosphorus (%)		Grain Yield (kg/ha)		Grain Protein (%)	
	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term
0	3.2	2.8	0.28	0.24	2044	1401	13.0	11.5
30	3.4	2.9	0.28	0.24	2306	1719	13.2	11.8
60	3.7	3.3	0.29	0.25	2807	2210	13.5	12.2
90	4.0	3.7	0.30	0.26	3149	2702	14.2	13.3
120	4.2	3.9	0.30	0.26	3225	2713	14.6	13.9
s.e	0.03		0.002		84		0.04	

Table 5. The effects of length of no-till and nitrogen rate on grain yield and grain protein in canola.

N Rate (kg/ha)	Grain Yield (kg/ha)		Grain Protein (%)	
	Long-term	Short-term	Long-term	Short-term
0	684	408	17.6	18.6
30	921	574	19.2	20.4
60	1383	983	21.7	17.6
90	1706	1424	17.1	17.4
120	1789	1572	19.3	21.2
s.e	70		0.2	

Table 6. The effects of length of no-till and nitrogen rate on soil residual NO₃-N in the soil (0-24" soil layer) from samples taken in the fall after harvest in 2006 after 5 years into the study.

N Rate (kg/ha)	Soil Residual NO ₃ -N	
	Long-term	Short-term
0	19.0	6.3
30	7.0	5.9
60	6.4	7.4
90	15.3	6.3
120	43.7	38.7

Table 7. The effects of nitrogen rate and placement of phosphorus on the grain yield of spring wheat (kg/ha). The means were averaged over the long-term and short-term no-till site.

N Rate (kg/ha)	Phosphorus Placement	
	Seed-Placed	Side-band
0	1727	1717
30	1949	2076
60	2499	2518
90	2939	2513
120	2914	3025
Mean	2406	2370
s.e.	84	

Table 8. The effects of nitrogen rate and placement of phosphorus on the grain yield of canola (kg/ha). The means were averaged over the long-term and short-term no-till site.

N Rate (kg/ha)	Phosphorus Placement	
	Seed-Placed	Side-band
0	556	536
30	760	734
60	1175	1140
90	1585	1544
120	1697	1663
Mean	1155	1123
s.e.	70	

Table 9. The effects of length of no-till on nitrogen balance (inputs and outputs of nitrogen).

N Rate (kg/ha)	Total N applied (5 years)		Total N removed with grain (kg/ha)		Nitrogen Balance (kg/ha) (applied N – N in grain)	
	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term
0	0	0	183	109	-183	-109
30	150	150	221	140	-71	+10
60	300	300	294	197	+6	+103
90	450	450	360	282	+90	+172
120	600	600	386	314	+214	+286

4.3.1. The response of spring wheat and field pea to rates of phosphorus fertilizer under long-term and short-term no till.

A high clearance hoe-press drill was used consisting of 10 openers on 8” spacing with the nitrogen mid-row banded between every second opener. The phosphorus was placed with the seed. Rates of 0, 10, 20, 30 and 40 lbs P₂O₅/acre were used with mono-ammonium phosphorus as the phosphorus fertilizer source. Two replicates were used for the experiment. A crop sequence of wheat-pea was used with both crops grown every year on both the long-term and short-term no-till site. Crops were grown on the other crop stubble i.e. pea on wheat stubble and wheat on pea stubble. The same plots were used every year for the various rates so that the cumulative effect of the phosphorus fertilizer rates could be determined over time and establish the maintenance rate.

Field Pea: A combined analysis of variance over years was done on the variables plant populations and grain yield. There was a linear decrease in plant populations as grain yield increased but no relationship on grain yield indicating the lack of an overall phosphorus response (Table 10).

A year x length of no-till was observed on grain yield (Table 11). The frost in 2004 was worst on the long-term site due to the lay of the land and there were more detrimental effects from excess water in 2005 on the long-term site due to poorer overall drainage relative to the short-term site thereby explaining the interaction.

Table 10. The effects of phosphorus rate on plant populations and grain yield in field pea.

Rate (lbs P ₂ O ₅ /acre)	Plant populations (# m ⁻²)	Grain Yield (kg/ha)
0	54	2730
10	50	2933
20	47	2773
30	44	3004
40	44	2805
s.e.	2	73

Table 11. The effects of field history and year on grain yield (kg/ha) in field pea.

Year	Long-term no-till	Short-term no-till
2003	3233	2518
2004	2950	3886
2005	1890	2078
2006	3151	3087
s.e.	93	

Spring wheat: A combined analysis over years for plant populations revealed a year effect and a year x length of no-till interaction and a quadratic response for the effects of phosphorus rates on plant populations. With grain yield, a year and rate of phosphorus effect (cubic response) was noted as well as a year x length of no-till and length of no-till x rate of phosphorus interaction.

A summary of rates of P on plant populations and grain yield is presented in Table 12. The rates of P had a quadratic effect which in turn has no agronomic effects. Regardless, more than 250 plants m⁻² was established which is more than adequate to maximize grain yield in any given

year. As far as grain yield, the cubic response makes very little agronomic sense and in essence we conclude that there was essentially no important response to phosphorus fertilizer.

A summary of the results for the interactions is presented in Tables 13-15. The rate of phosphorus effect was essentially not observed on the long-term site with a small response on the short-term site but the pattern of the response was not obvious (Table 13). The interaction between field history and year is due to the frost in 2004 which was more pronounced on the long-term site due to the lay of the land. In all years the grain yields were higher on the long-term no-till site except for 2004.

Table 12. The effects of phosphorus rate on plant populations and grain yield in spring wheat.

Rate (lbs P ₂ O ₅ /acre)	Plant populations (# m ⁻²)	Grain Yield (kg/ha)
0	296	2412
10	271	2374
20	276	2525
30	274	2748
40	297	2464
s.e.	10	80

Table 13. The effects of field history and rate of phosphorus on grain yield (kg/ha) in spring wheat.

Rate (lbs P ₂ O ₅ /acre)	Long-term no-till	Short-term no-till
0	2695	2130
10	2597	2150
20	2663	2388
30	2670	2826
40	2556	2371
s.e.	113	

Table 14. The effects of field history and year on plant populations (# m⁻²) in spring wheat.

Year	Long-term no-till	Short-term no-till
2003	151	191
2004	384	334
2005	332	333
2006	265	273
s.e.	13	

Table 15. The effects of field history and year on grain yield (kg/ha) in spring wheat.

Year	Long-term no-till	Short-term no-till
2003	2381	2031
2004	2382	2546
2005	2917	2240
2006	2864	2676
s.e.	101	

Effects of Field History on the Mineralization of Organic Nitrogen and Phosphorus: To reveal the effects of adopting low disturbance direct seeding on P availability over a longer time frame, in early spring of 2006, the plots were sampled from the long-term and short-term no-till sites. Treatments sampled included two stubble types (pea and wheat) with three different P fertilizer treatments (0, 20 and 40 kg P₂O₅/ha) Intact 0-15 cm soil cores were removed from each plot and incubated for two weeks in the laboratory. The supply rates of available phosphorus and nitrogen in the soil cores were measured over the two week period using PRS probes. The units of measurements are µg of ions absorbed per 10 cm² over the two weeks.

This comparison revealed significantly higher supplies of available nitrogen as nitrate and also higher supplies of available phosphorus on the long-term no-till site compared to the short term site (Figure 1). The effect of stubble type was most evident for nitrogen, with greater nitrate supply rates on pea stubble than wheat. The impact of added P fertilizer on increasing P supply was greatest on the long term no-till soil. This perhaps suggests greater fixation of P fertilizer into less soluble forms on the short term no-till compared to the long term.

The no-till systems that were evaluated appeared to generally have a positive effect on soil P availability in the short and long-term, with benefits that accrue over time. Stratification of P as a factor affecting P availability does not appear to be an issue, and tillage to address this does not seem warranted based on the results.

5.0 Conclusions

The adoption of no-till provides a solution to the issue of soil degradation and also the opportunity to increase the overall production capacity of our soils. A large amount of experience has been gained on the prairies with no-till. We need to focus on soil and crop management approaches that will enhance that potential even further. Any soil and crop management practices that increases the amount of organic carbon in the form of crop residues returned to the soil will enhance the overall health of the soil and its production capacity. The question is how high can we go? Can we surpass the native prairie? We need to look at the major limiting factors in each soil zone as a function of soil texture and develop soil and crop management strategies accordingly.

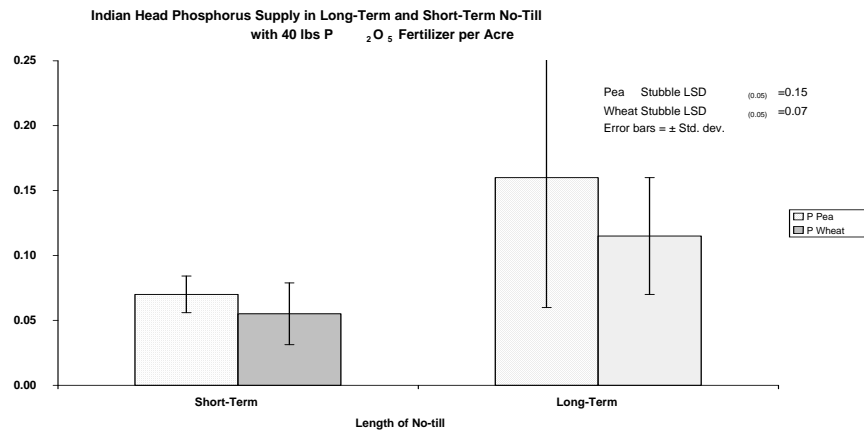
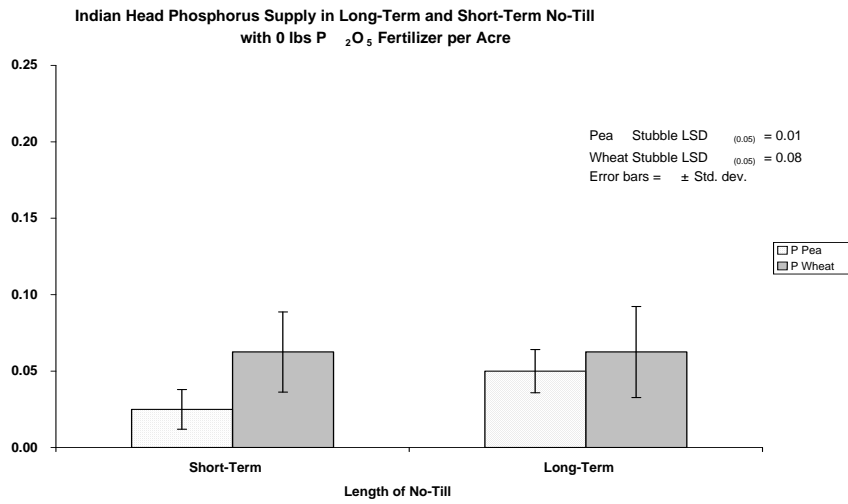
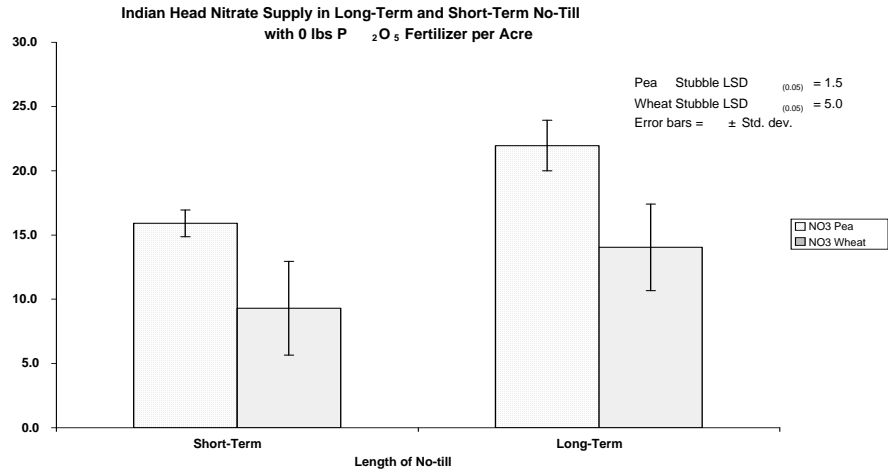


Figure 1. Nitrate and phosphate supply rates from the long-term and short-term no-till sites.

NOTICE: This paper was also published in the Proceedings of the FarmTech 2008 meetings held in Edmonton Alberta on January 30th and 31st and February 1st. The title of the paper was “**Long-Term Benefits of No-Till: What can we expect?**”

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